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# Search for Scalar Charm Quark Pair Production in $pp$ Collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector

G. Aad *et al.*\*

(ATLAS Collaboration)

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The results of a dedicated search for pair production of scalar partners of charm quarks are reported. The search is based on an integrated luminosity of  $20.3 \text{ fb}^{-1}$  of  $pp$  collisions at  $\sqrt{s} = 8$  TeV recorded with the ATLAS detector at the LHC. The search is performed using events with large missing transverse momentum and at least two jets, where the two leading jets are each tagged as originating from  $c$  quarks. Events containing isolated electrons or muons are vetoed. In an  $R$ -parity-conserving minimal supersymmetric scenario in which a single scalar-charm state is kinematically accessible, and where it decays exclusively into a charm quark and a neutralino, 95% confidence-level upper limits are obtained in the scalar-charm–neutralino mass plane such that, for neutralino masses below 200 GeV, scalar-charm masses up to 490 GeV are excluded.

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Supersymmetry (SUSY) [1–9] is a theory that extends the Standard Model (SM) and naturally resolves the hierarchy problem by introducing supersymmetric partners of the known bosons and fermions. In the framework of a generic  $R$ -parity-conserving minimal supersymmetric extension of the SM, the MSSM [10–14], SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) is stable, providing a possible candidate for dark matter. In a large variety of models, the LSP is the lightest neutralino,  $\tilde{\chi}_1^0$ .

The scalar partners (squarks) of various flavors of quarks may, rather generally, have different masses despite constraints on quark flavor mixing [15]. Recent searches disfavor low-mass top squarks (stops), sbottoms, and gluinos, so direct scalar-charm ( $\tilde{c}$ ) pair production could be the only squark production process accessible at the LHC. Searches for  $\tilde{c}$  states provide not only a possible supersymmetry discovery mode but also the potential to probe the flavor structure of the underlying theory.

Since no dedicated search for  $\tilde{c}$  has previously been performed, the best existing lower limits on  $\tilde{c}$  masses are obtained from searches for generic squark and gluino production at the LHC [16,17], and from the reinterpretation of LHC searches [18] for direct pair production of the scalar partner of the top quark followed by decays  $\tilde{t}_1 \rightarrow c + \tilde{\chi}_1^0$ . The top squark searches have a final state similar to that expected for scalar charm quarks, but are optimized for small  $m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$  mass differences, and so have

good sensitivity to the scalar charm quark only when  $m_{\tilde{c}} - m_{\tilde{\chi}_1^0} \lesssim m_W$ .

In this Letter, a dedicated search for direct  $\tilde{c}$  pair production is presented. The scalar charm quark is assumed to decay dominantly or exclusively via  $\tilde{c} \rightarrow c + \tilde{\chi}_1^0$ . The expected signal is therefore characterized by the presence of two jets originating from the hadronization of the  $c$  quarks, accompanied by missing transverse momentum ( $E_T^{\text{miss}}$ ) resulting from the undetected neutralinos.

The ATLAS detector is described in detail elsewhere [19]. This search uses  $pp$  collision data at a center-of-mass energy of 8 TeV recorded during 2012 at the LHC. After the application of beam, detector, and data quality requirements, the data set corresponds to a total integrated luminosity of  $20.3 \text{ fb}^{-1}$  with a 2.8% uncertainty, using the methods of Ref. [20].

The data are selected with a three-level trigger system that required a high transverse momentum ( $p_T$ ) jet and  $E_T^{\text{miss}}$  [21]. While events containing charged leptons (electrons or muons) in the search region are vetoed, single-lepton triggers are used for control regions. Events are required to have a reconstructed primary vertex consistent with the beam positions, and to meet basic quality criteria that suppress detector noise and noncollision backgrounds [22]. Jets are reconstructed from three-dimensional topological calorimeter energy clusters by using the anti- $k_t$  jet algorithm [23,24] with a radius parameter of 0.4. The measured jet energy is corrected for inhomogeneities and for the noncompensating response of the calorimeter by using  $p_{T-}$  and  $\eta$ -dependent [25] correction factors [26]. The impact of multiple overlapping  $pp$  interactions (pileup) is accounted for using a technique, based on jet areas, that provides an event-by-event and jet-by-jet correction [27]. Only jet candidates with  $p_T > 20$  GeV within  $|\eta| < 2.8$  are retained.

\*Full author list given at the end of the article.

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Electron candidates are required to have  $p_T > 7$  GeV,  $|\eta| < 2.47$  and to satisfy “medium” selection criteria [28]. Muon candidates are required to have  $p_T > 6$  GeV,  $|\eta| < 2.4$  and are identified by matching an extrapolated inner-detector track to one or more track segments in the muon spectrometer [29]. When defining lepton control regions, muons and electrons must meet additional “tight” selection criteria [29,30], and must satisfy track and calorimeter isolation criteria similar to those in Ref. [31].

Following this object reconstruction, overlaps between jet candidates and electrons or muons are resolved. Any jet within a distance  $\Delta R = 0.2$  of a medium quality electron candidate is discarded. Any remaining lepton within  $\Delta R = 0.4$  of a jet is discarded. Remaining muons must have longitudinal and transverse impact parameters within 1 mm and 0.2 mm of the primary vertex, respectively.

The calculation of  $E_T^{\text{miss}}$  is based on the vector sum of the calibrated  $p_T$  of reconstructed jets (with  $p_T > 20$  GeV and  $|\eta| < 4.5$ ), electrons, muons and photons, and the calorimeter energy clusters not belonging to these reconstructed objects [32].

Jets containing  $c$ -flavored hadrons without  $b$ -flavored parent hadrons are identified using an algorithm, optimized for charm tagging, based on a neural network that exploits both impact parameter and secondary vertex information and with a  $B$  to  $D$  decay chain vertex fitter [33]. This algorithm achieves a tagging efficiency of 19% (13%, 0.5%) for  $c$ -jets ( $b$ -jets, light-flavor or gluon jets) in  $t\bar{t}$  events. The efficiency for tagging  $b$ -jets is determined from measurements of dileptonic  $t\bar{t}$  events [34]. The  $c$ -jet tagging efficiency and its uncertainty have been calibrated in inclusive jet events over a range of  $p_T$  using jets from collision data containing  $D^*$  mesons [35]. Jets can be  $c$ -tagged only within the acceptance of the inner detector ( $|\eta| < 2.5$ ), so only such central jets are retained after the above selection.

Events are then required to have  $E_T^{\text{miss}} > 150$  GeV and one jet with  $p_T > 130$  GeV to ensure full trigger efficiency, as well as a second jet with  $p_T > 100$  GeV. The two highest- $p_T$  jets are required to be  $c$  tagged. The multijet background contribution with large  $E_T^{\text{miss}}$ , caused by mis-measurement of jet energies in the calorimeters or by neutrino production in heavy-quark decays, is suppressed by requiring a minimum azimuthal separation ( $\Delta\phi_{\text{min}}$ ) of 0.4 between the  $E_T^{\text{miss}}$  direction and any of the three leading jets. To reduce the effect of pileup, the third jet is exempted from this requirement if it has  $p_T < 50$  GeV,  $|\eta| < 2.4$  and less than half of the sum of its track  $p_T$  is associated with tracks matched to the primary vertex. In addition, the ratio of  $E_T^{\text{miss}}$  to the scalar sum of the transverse momenta of the two leading jets is required to be above one-third. Events containing residual electron or muon candidates are vetoed in order to reduce electroweak backgrounds.

After these requirements, the main SM processes contributing to the background are top quark pair and single

top production, together referred to as top production, as well as associated production of  $W/Z$  bosons with light- and heavy-flavor jets, referred to as  $W + \text{jets}$  and  $Z + \text{jets}$ . A selection based on the boost-corrected contranverse mass  $m_{\text{CT}}$  [36] is employed to further discriminate scalar-charm pair from top production. For two identical decays of heavy particles into two visible particles  $v_1$  and  $v_2$ , and into invisible particles, the contranverse mass [37] is defined as  $\{[E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2\}^{1/2}$ . The boost correction preserves the expected endpoint in the distribution against boosts caused by initial-state radiation. In the case of scalar-charm pair production with  $\tilde{c} \rightarrow c + \tilde{\chi}_1^0$ ,  $m_{\text{CT}}$  is expected to have an endpoint at  $(m_c^2 - m_{\tilde{\chi}_1^0}^2)/m_c$ . For  $t\bar{t}$  production, if both  $b$ -jets are mistagged as  $c$ -jets, the  $m_{\text{CT}}$  built using those two jets is expected to have a kinematic endpoint at 135 GeV.

To maximize the sensitivity across the  $\tilde{c}\tilde{\chi}_1^0$  mass plane, three overlapping signal regions (SR) are defined:  $m_{\text{CT}} > 150, 200, \text{ and } 250$  GeV. The remaining  $t\bar{t}$  background after the  $m_{\text{CT}}$  requirement mostly comprises events with one true  $c$ -jet from a  $W$  decay and a mistagged  $b$ -jet from a top quark decay. Events in which a  $Z$  boson is produced in association with heavy-flavor jets where the  $Z$  boson decays into  $\nu\bar{\nu}$  also enter the high- $m_{\text{CT}}$  regions. The heavy-flavor jets often originate from a gluon splitting,  $g \rightarrow c\bar{c}$ , which can lead to a small angular separation between the resulting  $c$ -jets and therefore a small invariant mass  $m_{cc}$ . The remaining  $t\bar{t}$  background is also concentrated at low  $m_{cc}$ . Consequently, a final requirement selects events for which the invariant mass of the two  $c$ -tagged jets is larger than 200 GeV.

Simulated-event samples are used to aid the description of the background and to model the SUSY signal. Top quark pair and single top production in the  $s$  and  $Wt$  channels are simulated with POWHEG-1.0 (R2092) [38], while the  $t$  channel single top production is simulated using ACERMC 3.8 [39]. A top quark mass of 172.5 GeV is used. The parton shower, fragmentation, and hadronization are performed with PYTHIA-6.426 [40]. Samples of  $W + \text{jets}$ ,  $Z + \text{jets}$ , and dibosons ( $WW$ ,  $WZ$ ,  $ZZ$ ) with light and heavy flavor jets are generated with SHERPA 1.4 [41], assuming massive  $b/c$  quarks. Samples of  $Zt\bar{t}$  and  $Wt\bar{t}$  are generated with MADGRAPH-5.1.3.33 [42] interfaced to PYTHIA-6.426. The signal samples are generated for a simplified SUSY model with only a single  $\tilde{c}$  state kinematically accessible, and with  $\text{BR}(\tilde{c} \rightarrow c + \tilde{\chi}_1^0) = 100\%$ , using MADGRAPH-5.1.5.11 interfaced to PYTHIA-6.427 for the parton shower, fragmentation, and hadronization. Signal cross sections are calculated to next-to-leading order in the strong coupling constant, adding the resummation of soft gluon emission at next-to-leading-logarithm accuracy (NLO + NLL) [43–45]. The uncertainty on each nominal cross section is defined by an envelope of predictions using different PDF sets and factorization and renormalization scales, as described in Ref. [46]. The Monte Carlo (MC)

samples are processed through a detector simulation [47] based on GEANT4 [48]. The effects of pileup are included in the simulation. Efficiency corrections derived from the data are applied to the simulation to correct for lepton efficiency as well as the tagging and mistagging rates.

The main SM process contributing to the background after all signal region selections is  $Z + \text{jets}$ , followed by  $W + \text{jets}$ , top quark pair, and single top production. Most  $t\bar{t}$  events contributing are  $t\bar{t} \rightarrow b\bar{b}\ell\nu qq$  events, in which either a  $\tau$  lepton decays hadronically, or an  $e$  or  $\mu$  is out of the geometric acceptance or not reconstructed or identified. Contributions from multijet, diboson, and associated production of  $t\bar{t}$  with  $W$ ,  $Z$  are subdominant. Noncollision backgrounds are found to be negligible.

The estimation of the main background processes is carried out by defining a set of three data control regions (CR) that do not overlap with each other or with the signal regions. The CRs are kinematically close to the SRs and each of them is enhanced in one or two of the backgrounds that is dominant in the SRs, while having low expected signal contamination (less than 1%). A statistical model is set up in which the background expectation in the CRs and SRs depends on several parameters of interest: the normalizations of the dominant backgrounds, top ( $t\bar{t}$  + single top),  $Z + \text{jets}$  and  $W + \text{jets}$ , as well as on nuisance parameters including the effect of uncertainties on the jet energy scale (JES) and resolution, calorimeter resolution for energy clusters not associated with any physics objects, energy scale and resolution of electrons and muons,  $c$ -tagging and mistagging rates, pileup, and luminosity. A profile likelihood fit of the background expectation to the data is performed simultaneously in all CRs [49], and from it the background normalizations are extracted. The normalization factors, which are consistent with unity within uncertainties, are then applied to the MC expectation in the signal regions.

The first control region is populated largely by  $t\bar{t}$  and  $W + \text{jets}$ . It contains events with exactly one isolated electron or muon with  $p_T$  above 50 GeV. The leading two jets, with  $p_T > 130$  and 50 GeV respectively, must be  $c$ -tagged. To select events containing  $W \rightarrow \ell\nu$ , the transverse mass of the  $(\ell, E_T^{\text{miss}})$  system is required to be between 40 and 100 GeV. The upper bound reduces possible signal contamination from SUSY models that produce leptons in cascade decays. Finally, it is required that  $E_T^{\text{miss}} > 100$  GeV and  $m_{CT} > 150$  GeV. The second control region is populated by  $Z \rightarrow \ell^+\ell^-$  events with two opposite-sign, same-flavor leptons, where the minimum  $p_T$  requirement is 70 GeV for the leading lepton and 7(6) GeV for the subleading electron (muon). The transverse momenta of the leptons are added vectorially to the  $\vec{E}_T^{\text{miss}}$  to mimic the  $Z \rightarrow \nu\bar{\nu}$  decay, and the modulus of the resulting two-vector is required to be larger than 100 GeV. The leading two jets are required to be  $c$ -tagged and their  $p_T$  must each be above 50 GeV. The invariant mass  $m_{\ell\ell}$  of

the two leptons is required to be between 75 and 105 GeV ( $Z$ -mass interval). A third control region, populated almost exclusively by dileptonic  $t\bar{t}$  events, contains events with two opposite-sign, different-flavor leptons, where the leading lepton has  $p_T > 25$  GeV and the subleading lepton  $p_T$  is above 7(6) GeV for electrons (muons). It is required that  $E_T^{\text{miss}} > 50$  GeV and  $m_{\ell\ell} > 50$  GeV. The leading two jets are required to be  $c$ -tagged and have  $p_T > 50$  GeV. In all CRs, events with additional lepton candidates beyond the required number of signal leptons are vetoed using the same lepton requirements used to veto events in the SRs.

The subdominant background contributions from dibosons,  $Zt\bar{t}$  and  $Wt\bar{t}$  are estimated by MC simulation. Finally, the residual multijet background is estimated using a data-driven technique based on the smearing of jets in a low- $E_T^{\text{miss}}$  data sample with jet response functions [50].

The experimental and theoretical uncertainties affecting the main backgrounds are correlated between control and signal regions, and the data observed in control regions constrain the uncertainties on the expected yields in the signal regions. The residual uncertainty due to the theoretical modeling of the top-production background is about 7%. It is evaluated using additional MC samples generated with ACERMC (where initial- and final-state radiation parameters are varied) an alternative fragmentation model (HERWIG), an alternative generator (MC@NLO), and by using diagram subtraction rather than diagram removal to account for the interference between  $t\bar{t}$  and single top  $Wt$ -channel production [51]. After the fit, the residual uncertainties on the  $W + \text{jets}$  and  $Z + \text{jets}$  theoretical modeling account for less than 20% of the total uncertainty. The dominant contributions to the residual uncertainty on the total background are from  $c$ -tagging ( $\sim 20\%$ ), normalization uncertainties related to the numbers of events in the CRs (10%–20%), and JES ( $\sim 10\%$ ).

For the SUSY signal processes, theoretical uncertainties on the cross section due to the choice of renormalization and factorization scales and from PDFs are found to be between 14% and 16% for  $\tilde{c}$  masses between 100 and 550 GeV. Prior to the fit, the detector-related uncertainties with largest impact on the signal event yields are those for  $c$ -tagging (typically 15%–30%) and JES (typically 10%–30%).

Table I reports the observed number of events and the SM predictions for each SR. The data are found to be below the SM background expectations, but consistent with them given the uncertainties. Figure 1 shows the measured  $m_{CT}$  and  $m_{cc}$  distributions in the  $m_{CT} > 150$  GeV region compared to the SM predictions. Monte Carlo estimates are shown after the normalizations extracted from the profile likelihood fit are applied. For illustrative purposes, the distributions expected for the simplified model with  $(\tilde{c}, \tilde{\chi}_1^0)$  masses of (400, 200) GeV and (550, 50) GeV are also shown.



TABLE I. Expected and observed number of events for an integrated luminosity of  $20.3 \text{ fb}^{-1}$  at  $\sqrt{s} = 8 \text{ TeV}$ . Top, Z + jets and W + jets contributions are estimated using the fit described in the text. For comparison, the numbers obtained using MC simulations only are shown in parentheses. The row labeled “Others” reports subdominant electroweak backgrounds estimated from MC simulations. The total uncertainties are also reported.

$m_{CT} \text{ (GeV)}$	>150	>200	>250
Top	$7.4 \pm 2.7 \text{ (7.1)}$	$3.9 \pm 1.6 \text{ (3.7)}$	$1.6 \pm 0.7 \text{ (1.5)}$
Z + jets	$14 \pm 3 \text{ (13)}$	$7.7 \pm 1.7 \text{ (7.0)}$	$4.3 \pm 1.2 \text{ (3.9)}$
W + jets	$7.2 \pm 4.5 \text{ (7.4)}$	$4.1 \pm 2.6 \text{ (4.2)}$	$1.9 \pm 1.2 \text{ (1.9)}$
Multijets	$0.3 \pm 0.3$	$0.2 \pm 0.2$	$0.05 \pm 0.05$
Others	$0.5 \pm 0.3$	$0.4 \pm 0.3$	$0.4 \pm 0.3$
<b>Total</b>	<b><math>30 \pm 6</math></b>	<b><math>16 \pm 3</math></b>	<b><math>8.2 \pm 1.9</math></b>
<b>Data</b>	<b>19</b>	<b>11</b>	<b>4</b>

Since no significant excesses are observed, the results are translated into 95% confidence-level (C.L.) upper limits on contributions from non-SM processes using the  $\text{CL}_s$  prescription [52]. Figure 2 shows the observed and expected exclusion limits at 95% C.L. on the  $\tilde{c}\text{-}\tilde{\chi}_1^0$  mass plane, assuming a single accessible  $\tilde{c}$  particle with

$\text{BR}(\tilde{c} \rightarrow c + \tilde{\chi}_1^0) = 100\%$ . The SR with the best expected sensitivity at each point in the plot is adopted as the nominal result. In the region where the  $c$ -tagged analysis of the ATLAS  $\tilde{t} \rightarrow c + \tilde{\chi}_1^0$  search [18] provides a stronger expected limit, i.e., for  $m_{\tilde{c}} - m_{\tilde{\chi}_1^0} \lesssim m_W$ , that result is used. The region excluded by the ATLAS monojet search described in Ref. [18] is shown separately as a grey shaded area. Systematic uncertainties, other than in the  $\tilde{c}$  pair-production cross section, are treated as nuisance parameters and correlated when appropriate. For the SUSY scenario considered, the upper limit at 95% C.L. on the scalar-charm mass obtained in the most conservative cross-section hypothesis is 540 GeV for  $m_{\tilde{\chi}_1^0} = 0$  (increasing to 555 GeV for the central estimate of the signal cross section). Neutralino masses up to 200 GeV are similarly

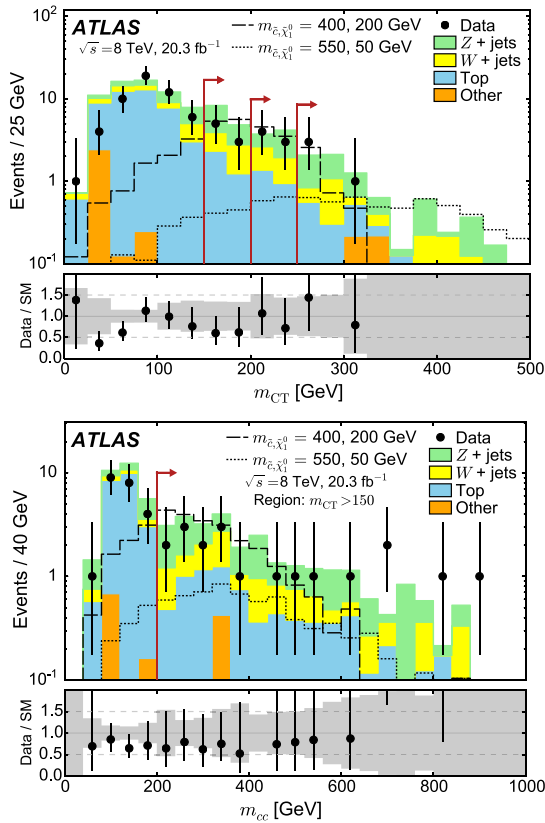


FIG. 1 (color online). Distributions of  $m_{CT}$  (top) and  $m_{cc}$  (bottom), and their corresponding SM predictions. Signal region selections ( $m_{CT} > 150 \text{ GeV}$  for the  $m_{cc}$  distribution) are applied, other than for the variable plotted. Arrows indicate the SR requirements on  $m_{CT}$  and  $m_{cc}$ . In the ratio plots, the grey bands correspond to the combined MC statistical and experimental systematic uncertainty.

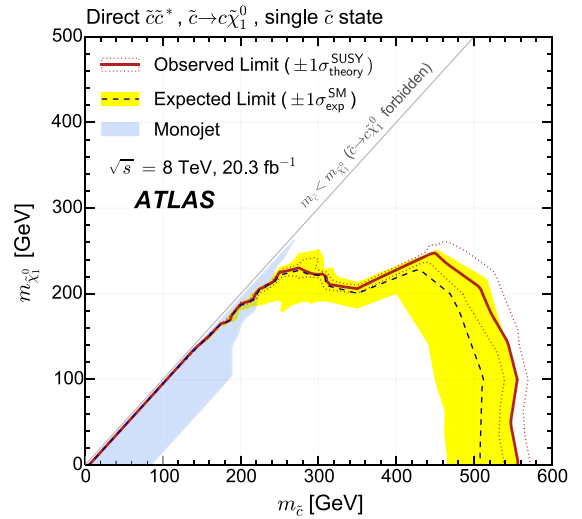


FIG. 2 (color online). Exclusion limits at 95% C.L. in the  $\tilde{c}\text{-}\tilde{\chi}_1^0$  mass plane. The observed (solid red line) and expected (dashed blue line) limits include all uncertainties except for the theoretical signal cross-section uncertainty (PDF and scale). The band around the expected limits show  $\pm 1\sigma$  uncertainties. The dotted lines around the observed limits represent the results obtained when moving the nominal signal cross section up or down by the  $\pm 1\sigma$  theoretical uncertainty.

excluded for  $m_{\tilde{c}} < 490$  GeV. This significantly extends the results of previous flavor-blind analyses [16,17], which provide no exclusion for  $m_{\tilde{\chi}_1^0} > 160$  GeV, nor for single light squarks with masses above 440 GeV. The signal regions are used to set limits on the effective cross sections  $\sigma_{\text{vis}}$  of any non-SM processes, including the effects of branching ratios, experimental acceptance, and efficiency, neglecting any possible contamination in the control regions. Values of  $\sigma_{\text{vis}}$  larger than 0.44 fb, 0.36 fb, and 0.23 fb are excluded at 95% C.L. for  $m_{\text{CT}}$  greater than 150, 200, and 250 GeV respectively.

In summary, this Letter reports results of a search for scalar-charm pair production in 8 TeV  $pp$  collisions at the LHC, based on  $20.3 \text{ fb}^{-1}$  of ATLAS data. The selected events have large  $E_{\text{T}}^{\text{miss}}$  and two  $c$ -tagged jets. The results are in agreement with SM predictions for backgrounds and translate into 95% C.L. upper limits on scalar-charm and neutralino masses in a simplified model with a single accessible  $\tilde{c}$  state for which the exclusive decay  $\tilde{c} \rightarrow c + \tilde{\chi}_1^0$  is assumed. For neutralino masses below 200 GeV, scalar-charm masses up to 490 GeV are excluded, significantly extending previous limits.

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Chu,<sup>152</sup> J. Chudoba,<sup>127</sup> J. J. Chwastowski,<sup>39</sup> L. Chytka,<sup>115</sup> G. Ciapetti,<sup>133a,133b</sup> A. K. Ciftci,<sup>4a</sup> D. Cinca,<sup>53</sup> V. Cindro,<sup>75</sup> A. Ciocio,<sup>15</sup> Z. H. Citron,<sup>173</sup> M. Citterio,<sup>91a</sup> M. Ciubancan,<sup>26a</sup> A. Clark,<sup>49</sup> P. J. Clark,<sup>46</sup> R. N. Clarke,<sup>15</sup> W. Cleland,<sup>125</sup> C. Clement,<sup>147a,147b</sup> Y. Coadou,<sup>85</sup> M. Cobal,<sup>165a,165c</sup> A. Coccaro,<sup>139</sup> J. Cochran,<sup>64</sup> L. Coffey,<sup>23</sup> J. G. Cogan,<sup>144</sup> B. Cole,<sup>35</sup> S. Cole,<sup>108</sup> A. P. Colijn,<sup>107</sup> J. Collot,<sup>55</sup> T. Colombo,<sup>58c</sup> G. Compostella,<sup>101</sup> P. Conde Muiño,<sup>126a,126b</sup> E. Coniavitis,<sup>48</sup> S. H. Connell,<sup>146b</sup> I. A. Connelly,<sup>77</sup> S. M. Consonni,<sup>91a,91b</sup> V. Consorti,<sup>48</sup> S. Constantinescu,<sup>26a</sup> C. 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De Nooij,<sup>107</sup> D. De Pedis,<sup>133a</sup> A. De Salvo,<sup>133a</sup> U. De Sanctis,<sup>150</sup> A. De Santo,<sup>150</sup> J. B. De Vivie De Regie,<sup>117</sup> W. J. Dearnaley,<sup>72</sup> R. Debbe,<sup>25</sup> C. Debenedetti,<sup>138</sup> D. V. Dedovich,<sup>65</sup> I. Deigaard,<sup>107</sup> J. Del Peso,<sup>82</sup> T. Del Prete,<sup>124a,124b</sup> D. Delgove,<sup>117</sup> F. Deliot,<sup>137</sup> C. M. Delitzsch,<sup>49</sup> M. Deliyergiyev,<sup>75</sup> A. Dell'Acqua,<sup>30</sup> L. Dell'Asta,<sup>22</sup> M. Dell'Orso,<sup>124a,124b</sup> M. Della Pietra,<sup>104aj</sup> D. della Volpe,<sup>49</sup> M. Delmastro,<sup>5</sup> P. A. Delsart,<sup>55</sup> C. Deluca,<sup>107</sup> D. A. DeMarco,<sup>159</sup> S. Demers,<sup>177</sup> M. Demichev,<sup>65</sup> A. Demilly,<sup>80</sup> S. P. Denisov,<sup>130</sup> D. Derendarz,<sup>39</sup> J. E. Derkaoui,<sup>136d</sup> F. Derue,<sup>80</sup> P. Dervan,<sup>74</sup> K. Desch,<sup>21</sup> C. 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Dolejsi,<sup>129</sup> Z. Dolezal,<sup>129</sup> B. A. Dolgoshein,<sup>98,a</sup> M. Donadelli,<sup>24d</sup> S. Donati,<sup>124a,124b</sup> P. Dondero,<sup>121a,121b</sup> J. Donini,<sup>34</sup> J. Dopke,<sup>131</sup> A. Doria,<sup>104a</sup> M. T. Dova,<sup>71</sup> A. T. Doyle,<sup>53</sup> M. Dris,<sup>10</sup> E. Dubreuil,<sup>34</sup> E. Duchovni,<sup>173</sup> G. Duckeck,<sup>100</sup> O. A. Ducu,<sup>26a</sup> D. Duda,<sup>176</sup> A. Dudarev,<sup>30</sup> L. Duflot,<sup>117</sup> L. Duguid,<sup>77</sup> M. Dührssen,<sup>30</sup> M. Dunford,<sup>58a</sup> H. Duran Yildiz,<sup>4a</sup> M. Düren,<sup>52</sup> A. Durglishvili,<sup>51b</sup> D. Duschinger,<sup>44</sup> M. Dwuznik,<sup>38a</sup> M. Dyndal,<sup>38a</sup> W. Edson,<sup>2</sup> N. C. Edwards,<sup>46</sup> W. Ehrenfeld,<sup>21</sup> T. Eifert,<sup>30</sup> G. Eigen,<sup>14</sup> K. Einsweiler,<sup>15</sup> T. Ekelof,<sup>167</sup> M. El Kacimi,<sup>136c</sup> M. Ellert,<sup>167</sup> S. Elles,<sup>5</sup> F. Ellinghaus,<sup>83</sup> A. A. Elliot,<sup>170</sup> N. Ellis,<sup>30</sup> J. Elmsheuser,<sup>100</sup> M. Elsing,<sup>30</sup> D. Emelianov,<sup>131</sup> Y. Enari,<sup>156</sup> O. C. Endner,<sup>83</sup> M. Endo,<sup>118</sup> R. Engelmann,<sup>149</sup> J. Erdmann,<sup>43</sup> A. Ereditato,<sup>17</sup> D. Eriksson,<sup>147a</sup> G. Ernis,<sup>176</sup> J. Ernst,<sup>2</sup> M. Ernst,<sup>25</sup> S. Errede,<sup>166</sup> E. Ertel,<sup>83</sup> M. Escalier,<sup>117</sup> H. Esch,<sup>43</sup> C. Escobar,<sup>125</sup> B. Esposito,<sup>47</sup> A. I. Etienvre,<sup>137</sup> E. Etzion,<sup>154</sup> H. Evans,<sup>61</sup> A. Ezhilov,<sup>123</sup> L. Fabbri,<sup>20a,20b</sup> G. Facini,<sup>31</sup> R. M. Fakhruddinov,<sup>130</sup> S. Falciano,<sup>133a</sup> R. J. Falla,<sup>78</sup> J. Faltova,<sup>129</sup> Y. Fang,<sup>33a</sup> M. Fanti,<sup>91a,91b</sup> A. Farbin,<sup>8</sup> A. Farilla,<sup>135a</sup> T. Farooque,<sup>12</sup> S. Farrell,<sup>15</sup> S. M. 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Gazis,<sup>10</sup> P. Ge,<sup>33d</sup> Z. Gecse,<sup>169</sup> C. N. P. Gee,<sup>131</sup> D. A. A. Geerts,<sup>107</sup> Ch. Geich-Gimbel,<sup>21</sup> C. Gemme,<sup>50a</sup> M. H. Genest,<sup>55</sup> S. Gentile,<sup>133a,133b</sup> M. George,<sup>54</sup> S. George,<sup>77</sup> D. Gerbaudo,<sup>164</sup> A. Gershon,<sup>154</sup> H. Ghazlane,<sup>136b</sup> N. Ghodbane,<sup>34</sup> B. Giacobbe,<sup>20a</sup> S. Giagu,<sup>133a,133b</sup> V. Giangiobbe,<sup>12</sup> P. Giannetti,<sup>124a,124b</sup> F. Gianotti,<sup>30</sup> B. Gibbard,<sup>25</sup> S. M. Gibson,<sup>77</sup> M. Gilchriese,<sup>15</sup> T. P. S. Gillam,<sup>28</sup> D. Gillberg,<sup>30</sup> G. Gilles,<sup>34</sup> D. M. Gingrich,<sup>3,e</sup> N. Giokaris,<sup>9</sup> M. P. Giordani,<sup>165a,165c</sup> F. M. Giorgi,<sup>20a</sup> F. M. Giorgi,<sup>16</sup> P. F. Giraud,<sup>137</sup> D. Giugni,<sup>91a</sup> C. Giuliani,<sup>48</sup> M. Giulini,<sup>58b</sup> B. K. Gjelsten,<sup>119</sup> S. Gkaitatzis,<sup>155</sup> I. Gkialas,<sup>155</sup> E. L. Gkougkousis,<sup>117</sup> L. K. Gladilin,<sup>99</sup> C. Glasman,<sup>82</sup> J. Glatzer,<sup>30</sup> P. C. F. Glaysheer,<sup>46</sup> A. Glazov,<sup>42</sup> M. Goblirsch-Kolb,<sup>101</sup> J. R. Goddard,<sup>76</sup> J. Godlewski,<sup>39</sup> S. Goldfarb,<sup>89</sup> T. Golling,<sup>49</sup> D. Golubkov,<sup>130</sup> A. Gomes,<sup>126a,126b,126d</sup> R. Gonçalo,<sup>126a</sup> J. Goncalves Pinto Firmino Da Costa,<sup>137</sup> L. Gonella,<sup>21</sup> S. González de la Hoz,<sup>168</sup> G. Gonzalez Parra,<sup>12</sup> S. Gonzalez-Sevilla,<sup>49</sup> L. Goossens,<sup>30</sup> P. A. Gorbounov,<sup>97</sup> H. A. Gordon,<sup>25</sup> I. Gorelov,<sup>105</sup> B. Gorini,<sup>30</sup> E. Gorini,<sup>73a,73b</sup> A. Gorišek,<sup>75</sup> E. Gornicki,<sup>39</sup> A. T. Goshaw,<sup>45</sup> C. Gössling,<sup>43</sup> M. I. Gostkin,<sup>65</sup> M. Goughri,<sup>136a</sup> D. Goudami,<sup>136c</sup> A. G. Goussiou,<sup>139</sup> H. M. X. Grabas,<sup>138</sup> L. Graber,<sup>54</sup> I. Grabowska-Bold,<sup>38a</sup> P. Grafström,<sup>20a,20b</sup> K.-J. Grahn,<sup>42</sup> J. Gramling,<sup>49</sup> E. Gramstad,<sup>119</sup> S. Grancagnolo,<sup>16</sup> V. Grassi,<sup>149</sup> V. Gratchev,<sup>123</sup> H. M. Gray,<sup>30</sup> E. Graziani,<sup>135a</sup> Z. D. Greenwood,<sup>79,n</sup> K. Gregersen,<sup>78</sup> I. M. Gregor,<sup>42</sup> P. Grenier,<sup>144</sup> J. Griffiths,<sup>8</sup> A. A. Grillo,<sup>138</sup> K. Grimm,<sup>72</sup> S. Grinstein,<sup>12,o</sup> Ph. Gris,<sup>34</sup> Y. V. Grishkevich,<sup>99</sup> J.-F. Grivaz,<sup>117</sup> J. P. Grohs,<sup>44</sup> A. Grohsjean,<sup>42</sup> E. Gross,<sup>173</sup> J. Grosse-Knetter,<sup>54</sup> G. C. Grossi,<sup>134a,134b</sup> Z. J. Grout,<sup>150</sup> L. Guan,<sup>33b</sup> J. Guenther,<sup>128</sup> F. Guescini,<sup>49</sup> D. Guest,<sup>177</sup> O. Gueta,<sup>154</sup> E. Guido,<sup>50a,50b</sup> T. Guillemain,<sup>117</sup> S. Guindon,<sup>2</sup> U. Gul,<sup>53</sup> C. Gumpert,<sup>44</sup> J. Guo,<sup>33e</sup> S. Gupta,<sup>120</sup> P. Gutierrez,<sup>113</sup> N. G. Gutierrez Ortiz,<sup>53</sup> C. Gutschow,<sup>44</sup> N. Guttman,<sup>154</sup> C. Guyot,<sup>137</sup> C. Gwenlan,<sup>120</sup> C. B. Gwilliam,<sup>74</sup> A. Haas,<sup>110</sup> C. Haber,<sup>15</sup> H. K. Hadavand,<sup>8</sup> N. Haddad,<sup>136e</sup> P. Haefner,<sup>21</sup> S. Hageböck,<sup>21</sup> Z. Hajduk,<sup>39</sup> H. Hakobyan,<sup>178</sup> M. Haleem,<sup>42</sup> J. Haley,<sup>114</sup> D. Hall,<sup>120</sup> G. Halladjian,<sup>90</sup> G. D. Hallewell,<sup>85</sup> K. Hamacher,<sup>176</sup> P. Hamal,<sup>115</sup> K. Hamano,<sup>170</sup> M. Hamer,<sup>54</sup> A. Hamilton,<sup>146a</sup> S. Hamilton,<sup>162</sup> G. N. Hamity,<sup>146c</sup> P. G. Hamnett,<sup>42</sup> L. Han,<sup>33b</sup> K. Hanagaki,<sup>118</sup> K. Hanawa,<sup>156</sup> M. Hance,<sup>15</sup> P. 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Krasznahorkay,<sup>30</sup> J. K. Kraus,<sup>21</sup> A. Kravchenko,<sup>25</sup> S. Kreiss,<sup>110</sup> M. Kretz,<sup>58c</sup> J. Kretzschmar,<sup>74</sup> K. Kreutzfeldt,<sup>52</sup> P. Krieger,<sup>159</sup> K. Krizka,<sup>31</sup> K. Kroeninger,<sup>43</sup> H. Kroha,<sup>101</sup> J. Kroll,<sup>122</sup> J. Kroseberg,<sup>21</sup> J. Krstic,<sup>13</sup> U. Kruchonak,<sup>65</sup> H. Krüger,<sup>21</sup> N. Krumnack,<sup>64</sup> Z. V. Krumshcheyn,<sup>65</sup> A. Kruse,<sup>174</sup> M. C. Kruse,<sup>45</sup> M. Kruskal,<sup>22</sup> T. Kubota,<sup>88</sup> H. Kucuk,<sup>78</sup> S. Kудay,<sup>4c</sup> S. Kuehn,<sup>48</sup> A. Kugel,<sup>58c</sup> F. Kuger,<sup>175</sup> A. Kuhl,<sup>138</sup> T. Kuhl,<sup>42</sup> V. Kukhtin,<sup>65</sup> Y. Kulchitsky,<sup>92</sup> S. Kuleshov,<sup>32b</sup> M. Kuna,<sup>133a,133b</sup> T. Kunigo,<sup>68</sup> A. Kupco,<sup>127</sup> H. Kurashige,<sup>67</sup> Y. A. Kurochkin,<sup>92</sup> R. Kurumida,<sup>67</sup> V. 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Plazak,<sup>145a</sup> M.-A. Pleier,<sup>25</sup> V. Pleskot,<sup>129</sup> E. Plotnikova,<sup>65</sup> P. Plucinski,<sup>147a,147b</sup> D. Pluth,<sup>64</sup> R. Poettgen,<sup>83</sup> L. Poggioli,<sup>117</sup> D. Pohl,<sup>21</sup> G. Polesello,<sup>121a</sup> A. Policicchio,<sup>37a,37b</sup> R. Polifka,<sup>159</sup> A. Polini,<sup>20a</sup> C. S. Pollard,<sup>53</sup> V. Polychronakos,<sup>25</sup> K. Pommès,<sup>30</sup> L. Pontecorvo,<sup>133a</sup> B. G. Pope,<sup>90</sup> G. A. Popeneciu,<sup>26b</sup> D. S. Popovic,<sup>13</sup> A. Poppleton,<sup>30</sup> S. Pospisil,<sup>128</sup> K. Potamianos,<sup>15</sup> I. N. Potrap,<sup>65</sup> C. J. Potter,<sup>150</sup> C. T. Potter,<sup>116</sup> G. Poulard,<sup>30</sup> J. Poveda,<sup>30</sup> V. Pozdnyakov,<sup>65</sup> P. Pralavorio,<sup>85</sup> A. Pranko,<sup>15</sup> S. Prasad,<sup>30</sup> S. Prell,<sup>64</sup> D. Price,<sup>84</sup> J. Price,<sup>74</sup> L. E. Price,<sup>6</sup> M. Primavera,<sup>73a</sup> S. Prince,<sup>87</sup> M. Proissl,<sup>46</sup> K. Prokofiev,<sup>60c</sup> F. Prokoshin,<sup>32b</sup> E. Protopapadaki,<sup>137</sup> S. Protopopescu,<sup>25</sup> J. Proudfoot,<sup>6</sup> M. Przybycien,<sup>38a</sup> E. Ptacek,<sup>116</sup> D. Puddu,<sup>135a,135b</sup> E. Pueschel,<sup>86</sup> D. Pulton,<sup>149</sup> M. Purohit,<sup>25,ee</sup> P. Puzo,<sup>117</sup> J. Qian,<sup>89</sup> G. Qin,<sup>53</sup> Y. Qin,<sup>84</sup> A. Quadt,<sup>54</sup> D. R. Quarrie,<sup>15</sup> W. B. Quayle,<sup>165a,165b</sup> M. Queitsch-Maitland,<sup>84</sup> D. Quilty,<sup>53</sup> A. Qureshi,<sup>160b</sup> V. Radeka,<sup>25</sup> V. Radescu,<sup>42</sup> S. K. Radhakrishnan,<sup>149</sup> P. Radloff,<sup>116</sup> P. Rados,<sup>88</sup> F. Ragusa,<sup>91a,91b</sup> G. Rahal,<sup>179</sup> S. Rajagopalan,<sup>25</sup> M. Rammensee,<sup>30</sup> C. Rangel-Smith,<sup>167</sup> F. Rauscher,<sup>100</sup> S. Rave,<sup>83</sup> T. C. Rave,<sup>48</sup> T. Ravenscroft,<sup>53</sup> M. Raymond,<sup>30</sup> A. L. Read,<sup>119</sup> N. P. Readioff,<sup>74</sup> D. M. Rebuffi,<sup>121a,121b</sup> A. Redelbach,<sup>175</sup> G. Redlinger,<sup>25</sup> R. Reece,<sup>138</sup> K. Reeves,<sup>41</sup> L. Rehnisch,<sup>16</sup> H. Reisin,<sup>27</sup> M. Relich,<sup>164</sup> C. Rembser,<sup>30</sup> H. Ren,<sup>33a</sup> A. Renaud,<sup>117</sup> M. Rescigno,<sup>133a</sup> S. Resconi,<sup>91a</sup> O. L. Rezanova,<sup>109,d</sup> P. Reznicek,<sup>129</sup> R. Rezvani,<sup>95</sup> R. Richter,<sup>101</sup> E. Richter-Was,<sup>38b</sup> M. Ridel,<sup>80</sup> P. Rieck,<sup>16</sup> C. J. Riegel,<sup>176</sup> J. Rieger,<sup>54</sup> M. Rijssenbeek,<sup>149</sup> A. Rimoldi,<sup>121a,121b</sup> L. Rinaldi,<sup>20a</sup> E. Ritsch,<sup>62</sup> I. Riu,<sup>12</sup> F. Rizatdinova,<sup>114</sup> E. Rizvi,<sup>76</sup> S. H. Robertson,<sup>87,k</sup> A. Robichaud-Veronneau,<sup>87</sup> D. Robinson,<sup>28</sup> J. E. M. Robinson,<sup>84</sup> A. Robson,<sup>53</sup> C. Roda,<sup>124a,124b</sup> L. Rodrigues,<sup>30</sup> S. Roe,<sup>30</sup> O. Rønne,<sup>119</sup> S. Rolli,<sup>162</sup> A. Romaniouk,<sup>98</sup> M. Romano,<sup>20a,20b</sup> S. M. Romano Saez,<sup>34</sup> E. Romero Adam,<sup>168</sup> N. Rompotis,<sup>139</sup> M. Ronzani,<sup>48</sup> L. Roos,<sup>80</sup> E. Ros,<sup>168</sup> S. Rosati,<sup>133a</sup> K. Rosbach,<sup>48</sup> P. Rose,<sup>138</sup> P. L. Rosendahl,<sup>14</sup> O. Rosenthal,<sup>142</sup> V. Rossetti,<sup>147a,147b</sup> E. Rossi,<sup>104a,104b</sup> L. P. Rossi,<sup>50a</sup> R. Rosten,<sup>139</sup> M. Rotaru,<sup>26a</sup> I. Roth,<sup>173</sup> J. Rothberg,<sup>139</sup> D. Rousseau,<sup>117</sup> C. R. Royon,<sup>137</sup> A. Rozanov,<sup>85</sup> Y. Rozen,<sup>153</sup> X. Ruan,<sup>146c</sup> F. Rubbo,<sup>12</sup> I. Rubinskiy,<sup>42</sup> V. I. Rud,<sup>99</sup> C. Rudolph,<sup>44</sup> M. S. Rudolph,<sup>159</sup> F. Rühr,<sup>48</sup> A. Ruiz-Martinez,<sup>30</sup> Z. Rurikova,<sup>48</sup> N. A. Rusakovich,<sup>65</sup> A. Ruschke,<sup>100</sup> H. L. Russell,<sup>139</sup> J. P. Rutherford,<sup>7</sup> N. Ruthmann,<sup>48</sup> Y. F. Ryabov,<sup>123</sup> M. Rybar,<sup>129</sup> G. Rybkin,<sup>117</sup> N. C. Ryder,<sup>120</sup> A. F. Saavedra,<sup>151</sup> G. Sabato,<sup>107</sup> S. Sacerdoti,<sup>27</sup> A. Saddique,<sup>3</sup> H. F.-W. Sadrozinski,<sup>138</sup> R. Sadykov,<sup>65</sup> F. Safai Tehrani,<sup>133a</sup> M. Saimpert,<sup>137</sup> H. Sakamoto,<sup>156</sup> Y. Sakurai,<sup>172</sup> G. Salamanna,<sup>135a,135b</sup> A. Salamon,<sup>134a</sup> M. Saleem,<sup>113</sup> D. Salek,<sup>107</sup> P. H. Sales De Bruin,<sup>139</sup> D. Salihagic,<sup>101</sup> A. Salnikov,<sup>144</sup> J. Salt,<sup>168</sup> D. Salvatore,<sup>37a,37b</sup> F. Salvatore,<sup>150</sup> A. Salvucci,<sup>106</sup> A. Salzburger,<sup>30</sup> D. Sampsonidis,<sup>155</sup> A. Sanchez,<sup>104a,104b</sup> J. Sánchez,<sup>168</sup> V. Sanchez Martinez,<sup>168</sup> H. Sandaker,<sup>14</sup> R. L. Sandbach,<sup>76</sup> H. G. Sander,<sup>83</sup> M. P. Sanders,<sup>100</sup> M. Sandhoff,<sup>176</sup> C. Sandoval,<sup>163</sup> R. Sandstroem,<sup>101</sup> D. P. C. Sankey,<sup>131</sup> A. Sansoni,<sup>47</sup> C. Santoni,<sup>34</sup> R. Santonic,<sup>134a,134b</sup> H. Santos,<sup>126a</sup> I. Santoyo Castillo,<sup>150</sup> K. Sapp,<sup>125</sup> A. Sapronov,<sup>65</sup> J. G. Saraiva,<sup>126a,126d</sup> B. Sarrazin,<sup>21</sup> O. Sasaki,<sup>66</sup> Y. Sasaki,<sup>156</sup> K. Sato,<sup>161</sup> G. Sauvage,<sup>5,a</sup> E. Sauvan,<sup>5</sup> G. Savage,<sup>77</sup> P. Savard,<sup>159,e</sup> C. Sawyer,<sup>120</sup> L. Sawyer,<sup>79,n</sup> D. H. Saxon,<sup>53</sup> J. Saxon,<sup>31</sup> C. Sbarra,<sup>20a</sup> A. Sbrizzi,<sup>20a,20b</sup> T. Scanlon,<sup>78</sup> D. A. Scannicchio,<sup>164</sup> M. Scarcella,<sup>151</sup> V. Scarfone,<sup>37a,37b</sup> J. Schaarschmidt,<sup>173</sup> P. Schacht,<sup>101</sup> D. Schaefer,<sup>30</sup> R. Schaefer,<sup>42</sup> J. Schaeffer,<sup>83</sup> S. Schaepe,<sup>21</sup> S. Schaezel,<sup>58b</sup> U. Schäfer,<sup>83</sup> A. C. Schaffer,<sup>117</sup> D. Schaile,<sup>100</sup> R. D. Schamberger,<sup>149</sup> V. Scharf,<sup>58a</sup> V. A. Schegelsky,<sup>123</sup> D. Scheirich,<sup>129</sup> M. Schernau,<sup>164</sup> C. Schiavi,<sup>50a,50b</sup> J. Schieck,<sup>100</sup> C. Schillo,<sup>48</sup> M. Schioppa,<sup>37a,37b</sup> S. Schlenker,<sup>30</sup> E. Schmidt,<sup>48</sup> K. Schmieden,<sup>30</sup> C. Schmitt,<sup>83</sup> S. Schmitt,<sup>58b</sup> B. Schneider,<sup>160a</sup> Y. J. Schnellbach,<sup>74</sup> U. Schnoor,<sup>44</sup> L. Schoeffel,<sup>137</sup> A. Schoening,<sup>58b</sup> B. D. Schoenrock,<sup>90</sup> A. L. S. Schorlemmer,<sup>54</sup> M. Schott,<sup>83</sup> D. Schouten,<sup>160a</sup> J. Schovancova,<sup>8</sup> S. Schramm,<sup>159</sup> M. Schreyer,<sup>175</sup> C. Schroeder,<sup>83</sup> N. Schuh,<sup>83</sup> M. J. Schultens,<sup>21</sup> H.-C. Schultz-Coulon,<sup>58a</sup> H. Schulz,<sup>16</sup> M. Schumacher,<sup>48</sup> B. A. Schumm,<sup>138</sup> Ph. Schune,<sup>137</sup> C. Schwanenberger,<sup>84</sup> A. Schwartzman,<sup>144</sup> T. A. Schwarz,<sup>89</sup> Ph. Schwegler,<sup>101</sup> Ph. Schwemling,<sup>137</sup> R. Schwienhorst,<sup>90</sup> J. Schwindling,<sup>137</sup> T. Schwindt,<sup>21</sup> M. Schwoerer,<sup>5</sup> F. G. Sciacca,<sup>17</sup> E. Scifo,<sup>117</sup> G. Sciolla,<sup>23</sup> F. Scuri,<sup>124a,124b</sup> F. Scutti,<sup>21</sup> J. Searcy,<sup>89</sup> G. Sedov,<sup>42</sup> E. Sedykh,<sup>123</sup> P. Seema,<sup>21</sup> S. C. Seidel,<sup>105</sup> A. Seiden,<sup>138</sup> F. Seifert,<sup>128</sup> J. M. Seixas,<sup>24a</sup> G. Sekhniadze,<sup>104a</sup> S. J. Sekula,<sup>40</sup> K. E. Selbach,<sup>46</sup>

- D. M. Seliverstov,<sup>123,a</sup> N. Semprini-Cesari,<sup>20a,20b</sup> C. Serfon,<sup>30</sup> L. Serin,<sup>117</sup> L. Serkin,<sup>54</sup> T. Serre,<sup>85</sup> R. Seuster,<sup>160a</sup>  
H. Severini,<sup>113</sup> T. Sfiligoj,<sup>75</sup> F. Sforza,<sup>101</sup> A. Sfyrta,<sup>30</sup> E. Shabalina,<sup>54</sup> M. Shamim,<sup>116</sup> L. Y. Shan,<sup>33a</sup> R. Shang,<sup>166</sup>  
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L. Shi,<sup>152,ff</sup> S. Shimizu,<sup>67</sup> C. O. Shimmin,<sup>164</sup> M. Shimojima,<sup>102</sup> M. Shiyakova,<sup>65</sup> A. Shmeleva,<sup>96</sup> D. Shoaleh Saadi,<sup>95</sup>  
M. J. Shochet,<sup>31</sup> S. Shojaii,<sup>91a,91b</sup> S. Shrestha,<sup>111</sup> E. Shulga,<sup>98</sup> M. A. Shupe,<sup>7</sup> S. Shushkevich,<sup>42</sup> P. Sicho,<sup>127</sup>  
O. Sidiropoulou,<sup>175</sup> D. Sidorov,<sup>114</sup> A. Sidoti,<sup>20a,20b</sup> F. Siegert,<sup>44</sup> Dj. Sijacki,<sup>13</sup> J. Silva,<sup>126a,126d</sup> Y. Silver,<sup>154</sup> D. Silverstein,<sup>144</sup>  
S. B. Silverstein,<sup>147a</sup> V. Simak,<sup>128</sup> O. Simard,<sup>5</sup> Lj. Simic,<sup>13</sup> S. Simion,<sup>117</sup> E. Simioni,<sup>83</sup> B. Simmons,<sup>78</sup> D. Simon,<sup>34</sup>  
R. Simoniello,<sup>91a,91b</sup> P. Sinervo,<sup>159</sup> N. B. Sinev,<sup>116</sup> G. Siragusa,<sup>175</sup> A. Sircar,<sup>79</sup> A. N. Sisakyan,<sup>65,a</sup> S. Yu. Sivoklov,<sup>99</sup>  
J. Sjölin,<sup>147a,147b</sup> T. B. Sjursen,<sup>14</sup> M. B. Skinner,<sup>72</sup> H. P. Skottowe,<sup>57</sup> P. Skubic,<sup>113</sup> M. Slater,<sup>18</sup> T. Slavicek,<sup>128</sup>  
M. Slawinska,<sup>107</sup> K. Sliwa,<sup>162</sup> V. Smakhtin,<sup>173</sup> B. H. Smart,<sup>46</sup> L. Smestad,<sup>14</sup> S. Yu. Smirnov,<sup>98</sup> Y. Smirnov,<sup>98</sup>  
L. N. Smirnova,<sup>99,gg</sup> O. Smirnova,<sup>81</sup> K. M. Smith,<sup>53</sup> M. Smith,<sup>35</sup> M. Smizanska,<sup>72</sup> K. Smolek,<sup>128</sup> A. A. Snesarev,<sup>96</sup>  
G. Snidero,<sup>76</sup> S. Snyder,<sup>25</sup> R. Sobie,<sup>170,k</sup> F. Socher,<sup>44</sup> A. Soffer,<sup>154</sup> D. A. Soh,<sup>152,ff</sup> C. A. Solans,<sup>30</sup> M. Solar,<sup>128</sup> J. Solc,<sup>128</sup>  
E. Yu. Soldatov,<sup>98</sup> U. Soldevila,<sup>168</sup> A. A. Solodkov,<sup>130</sup> A. Soloshenko,<sup>65</sup> O. V. Solovyanov,<sup>130</sup> V. Solovyeve,<sup>123</sup> P. Sommer,<sup>48</sup>  
H. Y. Song,<sup>33b</sup> N. Soni,<sup>1</sup> A. Sood,<sup>15</sup> A. Sopczak,<sup>128</sup> B. Sopko,<sup>128</sup> V. Sopko,<sup>128</sup> V. Sorin,<sup>12</sup> D. Sosa,<sup>58b</sup> M. Sosebee,<sup>8</sup>  
C. L. Sotiropoulou,<sup>155</sup> R. Soualah,<sup>165a,165c</sup> P. Soueid,<sup>95</sup> A. M. Soukharev,<sup>109,d</sup> D. South,<sup>42</sup> S. Spagnolo,<sup>73a,73b</sup> F. Spanò,<sup>77</sup>  
W. R. Spearman,<sup>57</sup> F. Spettel,<sup>101</sup> R. Spighi,<sup>20a</sup> G. Spigo,<sup>30</sup> L. A. Spiller,<sup>88</sup> M. Spousta,<sup>129</sup> T. Spreitzer,<sup>159</sup> R. D. St. Denis,<sup>53,a</sup>  
S. Staerz,<sup>44</sup> J. Stahlman,<sup>122</sup> R. Stamen,<sup>58a</sup> S. Stamm,<sup>16</sup> E. Stanecka,<sup>39</sup> C. Stanescu,<sup>135a</sup> M. Stanescu-Bellu,<sup>42</sup>  
M. M. Stanitzki,<sup>42</sup> S. Stapnes,<sup>119</sup> E. A. Starchenko,<sup>130</sup> J. Stark,<sup>55</sup> P. Staroba,<sup>127</sup> P. Starovoitov,<sup>42</sup> R. Staszewski,<sup>39</sup>  
P. Stavina,<sup>145a,a</sup> P. Steinberg,<sup>25</sup> B. Stelzer,<sup>143</sup> H. J. Stelzer,<sup>30</sup> O. Stelzer-Chilton,<sup>160a</sup> H. Stenzel,<sup>52</sup> S. Stern,<sup>101</sup> G. A. Stewart,<sup>53</sup>  
J. A. Stillings,<sup>21</sup> M. C. Stockton,<sup>87</sup> M. Stoebe,<sup>87</sup> G. Stoica,<sup>26a</sup> P. Stolte,<sup>54</sup> S. Stonjek,<sup>101</sup> A. R. Stradling,<sup>8</sup> A. Straessner,<sup>44</sup>  
M. E. Stramaglia,<sup>17</sup> J. Strandberg,<sup>148</sup> S. Strandberg,<sup>147a,147b</sup> A. Strandlie,<sup>119</sup> E. Strauss,<sup>144</sup> M. Strauss,<sup>113</sup> P. Strizenec,<sup>145b</sup>  
R. Ströhmer,<sup>175</sup> D. M. Strom,<sup>116</sup> R. Stroynowski,<sup>40</sup> A. Strubig,<sup>106</sup> S. A. Stucci,<sup>17</sup> B. Stugu,<sup>14</sup> N. A. Styles,<sup>42</sup> D. Su,<sup>144</sup> J. Su,<sup>125</sup>  
R. Subramaniam,<sup>79</sup> A. Succurro,<sup>12</sup> Y. Sugaya,<sup>118</sup> C. Suhr,<sup>108</sup> M. Suk,<sup>128</sup> V. V. Sulin,<sup>96</sup> S. Sultansoy,<sup>4c</sup> T. Sumida,<sup>68</sup> S. Sun,<sup>57</sup>  
X. Sun,<sup>33a</sup> J. E. Sundermann,<sup>48</sup> K. Suruliz,<sup>150</sup> G. Susinno,<sup>37a,37b</sup> M. R. Sutton,<sup>150</sup> Y. Suzuki,<sup>66</sup> M. Svatos,<sup>127</sup> S. Swedish,<sup>169</sup>  
M. Swiatlowski,<sup>144</sup> I. Sykora,<sup>145a</sup> T. Sykora,<sup>129</sup> D. Ta,<sup>90</sup> C. Taccini,<sup>135a,135b</sup> K. Tackmann,<sup>42</sup> J. Taenzer,<sup>159</sup> A. Taffard,<sup>164</sup>  
R. Tafirout,<sup>160a</sup> N. Taiblum,<sup>154</sup> H. Takai,<sup>25</sup> R. Takashima,<sup>69</sup> H. Takeda,<sup>67</sup> T. Takeshita,<sup>141</sup> Y. Takubo,<sup>66</sup> M. Talby,<sup>85</sup>  
A. A. Talyshev,<sup>109,d</sup> J. Y. C. Tam,<sup>175</sup> K. G. Tan,<sup>88</sup> J. Tanaka,<sup>156</sup> R. Tanaka,<sup>117</sup> S. Tanaka,<sup>132</sup> S. Tanaka,<sup>66</sup> A. J. Tanasijczuk,<sup>143</sup>  
B. B. Tannenwald,<sup>111</sup> N. Tannoury,<sup>21</sup> S. Tapprogge,<sup>83</sup> S. Tarem,<sup>153</sup> F. Tarrade,<sup>29</sup> G. F. Tartarelli,<sup>91a</sup> P. Tas,<sup>129</sup> M. Tasevsky,<sup>127</sup>  
T. Tashiro,<sup>68</sup> E. Tassi,<sup>37a,37b</sup> A. Tavares Delgado,<sup>126a,126b</sup> Y. Tayalati,<sup>136d</sup> F. E. Taylor,<sup>94</sup> G. N. Taylor,<sup>88</sup> W. Taylor,<sup>160b</sup>  
F. A. Teischinger,<sup>30</sup> M. Teixeira Dias Castanheira,<sup>76</sup> P. Teixeira-Dias,<sup>77</sup> K. K. Temming,<sup>48</sup> H. Ten Kate,<sup>30</sup> P. K. Teng,<sup>152</sup>  
J. J. Teoh,<sup>118</sup> F. Tepel,<sup>176</sup> S. Terada,<sup>66</sup> K. Terashi,<sup>156</sup> J. Terron,<sup>82</sup> S. Terzo,<sup>101</sup> M. Testa,<sup>47</sup> R. J. Teuscher,<sup>159,k</sup> J. Therhaag,<sup>21</sup>  
T. Theveniaux-Pelzer,<sup>34</sup> J. P. Thomas,<sup>18</sup> J. Thomas-Wilsker,<sup>77</sup> E. N. Thompson,<sup>35</sup> P. D. Thompson,<sup>18</sup> R. J. Thompson,<sup>84</sup>  
A. S. Thompson,<sup>53</sup> L. A. Thomsen,<sup>36</sup> E. Thomson,<sup>122</sup> M. Thomson,<sup>28</sup> W. M. Thong,<sup>88</sup> R. P. Thun,<sup>89,a</sup> F. Tian,<sup>35</sup>  
M. J. Tibbetts,<sup>15</sup> R. E. Ticse Torres,<sup>85</sup> V. O. Tikhomirov,<sup>96,hh</sup> Yu. A. Tikhonov,<sup>109,d</sup> S. Timoshenko,<sup>98</sup> E. Tiouchichine,<sup>85</sup>  
P. Tipton,<sup>177</sup> S. Tisserant,<sup>85</sup> T. Todorov,<sup>5,a</sup> S. Todorova-Nova,<sup>129</sup> J. Tojo,<sup>70</sup> S. Tokár,<sup>145a</sup> K. Tokushuku,<sup>66</sup> K. Tollefson,<sup>90</sup>  
E. Tolley,<sup>57</sup> L. Tomlinson,<sup>84</sup> M. Tomoto,<sup>103</sup> L. Tompkins,<sup>144,ii</sup> K. Toms,<sup>105</sup> N. D. Topilin,<sup>65</sup> E. Torrence,<sup>116</sup> H. Torres,<sup>143</sup>  
E. Torró Pastor,<sup>168</sup> J. Toth,<sup>85,jj</sup> F. Touchard,<sup>85</sup> D. R. Tovey,<sup>140</sup> H. L. Tran,<sup>117</sup> T. Trefzger,<sup>175</sup> L. Tremblet,<sup>30</sup> A. Tricoli,<sup>30</sup>  
I. M. Trigger,<sup>160a</sup> S. Trincas-Duvoid,<sup>80</sup> M. F. Tripania,<sup>12</sup> W. Trischuk,<sup>159</sup> B. Trocmé,<sup>55</sup> C. Troncon,<sup>91a</sup>  
M. Trotter-McDonald,<sup>15</sup> M. Trovatelli,<sup>135a,135b</sup> P. True,<sup>90</sup> M. Trzebinski,<sup>39</sup> A. Trzupek,<sup>39</sup> C. Tsarouchas,<sup>30</sup> J. C-L. Tseng,<sup>120</sup>  
P. V. Tsiarashka,<sup>92</sup> D. Tsionou,<sup>137</sup> G. Tsipolitis,<sup>10</sup> N. Tsirintanis,<sup>9</sup> S. Tsiskaridze,<sup>12</sup> V. Tsiskaridze,<sup>48</sup> E. G. Tskhadadze,<sup>51a</sup>  
I. I. Tsukerman,<sup>97</sup> V. Tsulaia,<sup>15</sup> S. Tsuno,<sup>66</sup> D. Tsybychev,<sup>149</sup> A. Tudorache,<sup>26a</sup> V. Tudorache,<sup>26a</sup> A. N. Tuna,<sup>122</sup>  
S. A. Tupputi,<sup>20a,20b</sup> S. Turchikhin,<sup>99,gg</sup> D. Turecek,<sup>128</sup> I. Turk Cakir,<sup>4c</sup> R. Turra,<sup>91a,91b</sup> A. J. Turvey,<sup>40</sup> P. M. Tuts,<sup>35</sup>  
A. Tykhonov,<sup>49</sup> M. Tylmad,<sup>147a,147b</sup> M. Tyndel,<sup>131</sup> I. Ueda,<sup>156</sup> R. Ueno,<sup>29</sup> M. Ughetto,<sup>85</sup> M. Ugland,<sup>14</sup> M. Uhlenbrock,<sup>21</sup>  
F. Ukegawa,<sup>161</sup> G. Unal,<sup>30</sup> A. Undrus,<sup>25</sup> G. Unel,<sup>164</sup> F. C. Ungaro,<sup>48</sup> Y. Unno,<sup>66</sup> C. Unverdorben,<sup>100</sup> J. Urban,<sup>145b</sup>  
P. Urquijo,<sup>88</sup> P. Urrejola,<sup>83</sup> G. Usai,<sup>8</sup> A. Usanova,<sup>62</sup> L. Vacavant,<sup>85</sup> V. Vacek,<sup>128</sup> B. Vachon,<sup>87</sup> N. Valencic,<sup>107</sup>  
S. Valentinetti,<sup>20a,20b</sup> A. Valero,<sup>168</sup> L. Valery,<sup>12</sup> S. Valkar,<sup>129</sup> E. Valladolid Gallego,<sup>168</sup> S. Vallecorsa,<sup>49</sup> J. A. Valls Ferrer,<sup>168</sup>  
W. Van Den Wollenberg,<sup>107</sup> P. C. Van Der Deijl,<sup>107</sup> R. van der Geer,<sup>107</sup> H. van der Graaf,<sup>107</sup> R. Van Der Leeuw,<sup>107</sup>  
N. van Eldik,<sup>30</sup> P. van Gemmeren,<sup>6</sup> J. Van Nieuwkoop,<sup>143</sup> I. van Vulpen,<sup>107</sup> M. C. van Woerden,<sup>30</sup> M. Vanadia,<sup>133a,133b</sup>  
W. Vandelli,<sup>30</sup> R. Vanguri,<sup>122</sup> A. Vaniachine,<sup>6</sup> F. Vannucci,<sup>80</sup> G. Vardanyan,<sup>178</sup> R. Vari,<sup>133a</sup> E. W. Varnes,<sup>7</sup> T. Varol,<sup>40</sup>

D. Varouchas,<sup>80</sup> A. Vartapetian,<sup>8</sup> K. E. Varvell,<sup>151</sup> F. Vazeille,<sup>34</sup> T. Vazquez Schroeder,<sup>54</sup> J. Veatch,<sup>7</sup> F. Veloso,<sup>126a,126c</sup> T. Velz,<sup>21</sup> S. Veneziano,<sup>133a</sup> A. Ventura,<sup>73a,73b</sup> D. Ventura,<sup>86</sup> M. Venturi,<sup>170</sup> N. Venturi,<sup>159</sup> A. Venturini,<sup>23</sup> V. Vercesi,<sup>121a</sup> M. Verducci,<sup>133a,133b</sup> W. Verkerke,<sup>107</sup> J. C. Vermeulen,<sup>107</sup> A. Vest,<sup>44</sup> M. C. Vetterli,<sup>143,e</sup> O. Viazlo,<sup>81</sup> I. Vichou,<sup>166</sup> T. Vickey,<sup>146c,kk</sup> O. E. Vickey Boeriu,<sup>146c</sup> G. H. A. Viehhauser,<sup>120</sup> S. Viel,<sup>15</sup> R. Vigne,<sup>30</sup> M. Villa,<sup>20a,20b</sup> M. Villaplana Perez,<sup>91a,91b</sup> E. Vilucchi,<sup>47</sup> M. G. Vinciter,<sup>29</sup> V. B. Vinogradov,<sup>65</sup> J. Virzi,<sup>15</sup> I. Vivarelli,<sup>150</sup> F. Vives Vaque,<sup>3</sup> S. Vlachos,<sup>10</sup> D. Vladoiu,<sup>100</sup> M. Vlasak,<sup>128</sup> M. Vogel,<sup>32a</sup> P. Vokac,<sup>128</sup> G. Volpi,<sup>124a,124b</sup> M. Volpi,<sup>88</sup> H. von der Schmitt,<sup>101</sup> H. von Radziewski,<sup>48</sup> E. von Toerne,<sup>21</sup> V. Vorobel,<sup>129</sup> K. Vorobev,<sup>98</sup> M. Vos,<sup>168</sup> R. Voss,<sup>30</sup> J. H. Vosseveld,<sup>74</sup> N. Vranjes,<sup>13</sup> M. Vranjes Milosavljevic,<sup>13</sup> V. Vrba,<sup>127</sup> M. Vreeswijk,<sup>107</sup> R. Vuillermet,<sup>30</sup> I. Vukotic,<sup>31</sup> Z. Vykydal,<sup>128</sup> P. Wagner,<sup>21</sup> W. Wagner,<sup>176</sup> H. Wahlberg,<sup>71</sup> S. Wahrmond,<sup>44</sup> J. Wakabayashi,<sup>103</sup> J. Walder,<sup>72</sup> R. Walker,<sup>100</sup> W. Walkowiak,<sup>142</sup> C. Wang,<sup>33c</sup> F. Wang,<sup>174</sup> H. Wang,<sup>15</sup> H. Wang,<sup>40</sup> J. Wang,<sup>42</sup> J. Wang,<sup>33a</sup> K. Wang,<sup>87</sup> R. Wang,<sup>105</sup> S. M. Wang,<sup>152</sup> T. Wang,<sup>21</sup> X. Wang,<sup>177</sup> C. Wanotayaroj,<sup>116</sup> A. Warburton,<sup>87</sup> C. P. Ward,<sup>28</sup> D. R. Wardrope,<sup>78</sup> M. Warsinsky,<sup>48</sup> A. Washbrook,<sup>46</sup> C. Wasicki,<sup>42</sup> P. M. Watkins,<sup>18</sup> A. T. Watson,<sup>18</sup> I. J. Watson,<sup>151</sup> M. F. Watson,<sup>18</sup> G. Watts,<sup>139</sup> S. Watts,<sup>84</sup> B. M. Waugh,<sup>78</sup> S. Webb,<sup>84</sup> M. S. Weber,<sup>17</sup> S. W. Weber,<sup>175</sup> J. S. Webster,<sup>31</sup> A. R. Weidberg,<sup>120</sup> B. Weinert,<sup>61</sup> J. Weingarten,<sup>54</sup> C. Weiser,<sup>48</sup> H. Weits,<sup>107</sup> P. S. Wells,<sup>30</sup> T. Wenaus,<sup>25</sup> D. Wendland,<sup>16</sup> T. Wengler,<sup>30</sup> S. Wenig,<sup>30</sup> N. Wermes,<sup>21</sup> M. Werner,<sup>48</sup> P. Werner,<sup>30</sup> M. Wessels,<sup>58a</sup> J. Wetter,<sup>162</sup> K. Whalen,<sup>29</sup> A. M. Wharton,<sup>72</sup> A. White,<sup>8</sup> M. J. White,<sup>1</sup> R. White,<sup>32b</sup> S. White,<sup>124a,124b</sup> D. Whiteson,<sup>164</sup> D. Wicke,<sup>176</sup> F. J. Wickens,<sup>131</sup> W. Wiedenmann,<sup>174</sup> M. WIELERS,<sup>131</sup> P. Wienemann,<sup>21</sup> C. Wigglesworth,<sup>36</sup> L. A. M. Wiik-Fuchs,<sup>21</sup> A. Wildauer,<sup>101</sup> H. G. Wilkens,<sup>30</sup> H. H. Williams,<sup>122</sup> S. Williams,<sup>107</sup> C. Willis,<sup>90</sup> S. Willocq,<sup>86</sup> A. Wilson,<sup>89</sup> J. A. Wilson,<sup>18</sup> I. Wingerter-Seez,<sup>5</sup> F. Winklmeier,<sup>116</sup> B. T. Winter,<sup>21</sup> M. Wittgen,<sup>144</sup> J. Wittkowski,<sup>100</sup> S. J. Wollstadt,<sup>83</sup> M. W. Wolter,<sup>39</sup> H. Wolters,<sup>126a,126c</sup> B. K. Wosiek,<sup>39</sup> J. Wotschack,<sup>30</sup> M. J. Woudstra,<sup>84</sup> K. W. Wozniak,<sup>39</sup> M. Wu,<sup>55</sup> S. L. Wu,<sup>174</sup> X. Wu,<sup>49</sup> Y. Wu,<sup>89</sup> T. R. Wyatt,<sup>84</sup> B. M. Wynne,<sup>46</sup> S. Xella,<sup>36</sup> D. Xu,<sup>33a</sup> L. Xu,<sup>33b,II</sup> B. Yabsley,<sup>151</sup> S. Yacoob,<sup>146b,mm</sup> R. Yakabe,<sup>67</sup> M. Yamada,<sup>66</sup> Y. Yamaguchi,<sup>118</sup> A. Yamamoto,<sup>66</sup> S. Yamamoto,<sup>156</sup> T. Yamanaka,<sup>156</sup> K. Yamauchi,<sup>103</sup> Y. Yamazaki,<sup>67</sup> Z. Yan,<sup>22</sup> H. Yang,<sup>33e</sup> H. Yang,<sup>174</sup> Y. Yang,<sup>152</sup> S. Yanush,<sup>93</sup> L. Yao,<sup>33a</sup> W-M. Yao,<sup>15</sup> Y. Yasu,<sup>66</sup> E. Yatsenko,<sup>42</sup> K. H. Yau Wong,<sup>21</sup> J. Ye,<sup>40</sup> S. Ye,<sup>25</sup> I. Yeletsikh,<sup>65</sup> A. L. Yen,<sup>57</sup> E. Yildirim,<sup>42</sup> K. Yorita,<sup>172</sup> R. Yoshida,<sup>6</sup> K. Yoshihara,<sup>122</sup> C. Young,<sup>144</sup> C. J. S. Young,<sup>30</sup> S. Youssef,<sup>22</sup> D. R. Yu,<sup>15</sup> J. Yu,<sup>8</sup> J. M. Yu,<sup>89</sup> J. Yu,<sup>114</sup> L. Yuan,<sup>67</sup> A. Yurkewicz,<sup>108</sup> I. Yusuff,<sup>28,nn</sup> B. Zabinski,<sup>39</sup> R. Zaidan,<sup>63</sup> A. M. Zaitsev,<sup>130,bb</sup> A. Zaman,<sup>149</sup> S. Zambito,<sup>23</sup> L. Zanello,<sup>133a,133b</sup> D. Zanzi,<sup>88</sup> C. Zeitnitz,<sup>176</sup> M. Zeman,<sup>128</sup> A. Zemla,<sup>38a</sup> K. Zengel,<sup>23</sup> O. Zenin,<sup>130</sup> T. Ženiš,<sup>145a</sup> D. Zerwas,<sup>117</sup> D. Zhang,<sup>89</sup> F. Zhang,<sup>174</sup> J. Zhang,<sup>6</sup> L. Zhang,<sup>152</sup> R. Zhang,<sup>33b</sup> X. Zhang,<sup>33d</sup> Z. Zhang,<sup>117</sup> X. Zhao,<sup>40</sup> Y. Zhao,<sup>33d</sup> Z. Zhao,<sup>33b</sup> A. Zhemchugov,<sup>65</sup> J. Zhong,<sup>120</sup> B. Zhou,<sup>89</sup> C. Zhou,<sup>45</sup> L. Zhou,<sup>35</sup> L. Zhou,<sup>40</sup> N. Zhou,<sup>164</sup> C. G. Zhu,<sup>33d</sup> H. Zhu,<sup>33a</sup> J. Zhu,<sup>89</sup> Y. Zhu,<sup>33b</sup> X. Zhuang,<sup>33a</sup> K. Zhukov,<sup>96</sup> A. Zibell,<sup>175</sup> D. Zieminska,<sup>61</sup> N. I. Zimine,<sup>65</sup> C. Zimmermann,<sup>83</sup> R. Zimmermann,<sup>21</sup> S. Zimmermann,<sup>48</sup> Z. Zinonos,<sup>54</sup> M. Ziolkowski,<sup>142</sup> L. Živković,<sup>13</sup> G. Zobernig,<sup>174</sup> A. Zoccoli,<sup>20a,20b</sup> M. zur Nedden,<sup>16</sup> G. Zurzolo,<sup>104a,104b</sup> and L. Zwalinski<sup>30</sup>

(ATLAS Collaboration)

<sup>1</sup>Department of Physics, University of Adelaide, Adelaide, Australia<sup>2</sup>Physics Department, SUNY Albany, Albany NY, United States of America<sup>3</sup>Department of Physics, University of Alberta, Edmonton AB, Canada<sup>4a</sup>Department of Physics, Ankara University, Ankara, Turkey<sup>4b</sup>Istanbul Aydin University, Istanbul, Turkey<sup>4c</sup>Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey<sup>5</sup>LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France<sup>6</sup>High Energy Physics Division, Argonne National Laboratory, Argonne IL, United States of America<sup>7</sup>Department of Physics, University of Arizona, Tucson AZ, United States of America<sup>8</sup>Department of Physics, The University of Texas at Arlington, Arlington TX, United States of America<sup>9</sup>Physics Department, University of Athens, Athens, Greece<sup>10</sup>Physics Department, National Technical University of Athens, Zografou, Greece<sup>11</sup>Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan<sup>12</sup>Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain<sup>13</sup>Institute of Physics, University of Belgrade, Belgrade, Serbia<sup>14</sup>Department for Physics and Technology, University of Bergen, Bergen, Norway<sup>15</sup>Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, United States of America<sup>16</sup>Department of Physics, Humboldt University, Berlin, Germany<sup>17</sup>Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland

- <sup>18</sup>*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*
- <sup>19a</sup>*Department of Physics, Bogazici University, Istanbul, Turkey*
- <sup>19b</sup>*Department of Physics, Dogus University, Istanbul, Turkey*
- <sup>19c</sup>*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*
- <sup>20a</sup>*INFN Sezione di Bologna, Italy*
- <sup>20b</sup>*Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*
- <sup>21</sup>*Physikalisches Institut, University of Bonn, Bonn, Germany*
- <sup>22</sup>*Department of Physics, Boston University, Boston MA, United States of America*
- <sup>23</sup>*Department of Physics, Brandeis University, Waltham MA, United States of America*
- <sup>24a</sup>*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*
- <sup>24b</sup>*Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*
- <sup>24c</sup>*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*
- <sup>24d</sup>*Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil*
- <sup>25</sup>*Physics Department, Brookhaven National Laboratory, Upton NY, United States of America*
- <sup>26a</sup>*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*
- <sup>26b</sup>*National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania*
- <sup>26c</sup>*University Politehnica Bucharest, Bucharest, Romania*
- <sup>26d</sup>*West University in Timisoara, Timisoara, Romania*
- <sup>27</sup>*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*
- <sup>28</sup>*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
- <sup>29</sup>*Department of Physics, Carleton University, Ottawa ON, Canada*
- <sup>30</sup>*CERN, Geneva, Switzerland*
- <sup>31</sup>*Enrico Fermi Institute, University of Chicago, Chicago IL, United States of America*
- <sup>32a</sup>*Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*
- <sup>32b</sup>*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*
- <sup>33a</sup>*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*
- <sup>33b</sup>*Department of Modern Physics, University of Science and Technology of China, Anhui, China*
- <sup>33c</sup>*Department of Physics, Nanjing University, Jiangsu, China*
- <sup>33d</sup>*School of Physics, Shandong University, Shandong, China*
- <sup>33e</sup>*Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai, China*
- <sup>33f</sup>*Physics Department, Tsinghua University, Beijing 100084, China*
- <sup>34</sup>*Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France*
- <sup>35</sup>*Nevis Laboratory, Columbia University, Irvington NY, United States of America*
- <sup>36</sup>*Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark*
- <sup>37a</sup>*INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy*
- <sup>37b</sup>*Dipartimento di Fisica, Università della Calabria, Rende, Italy*
- <sup>38a</sup>*AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland*
- <sup>38b</sup>*Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland*
- <sup>39</sup>*The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland*
- <sup>40</sup>*Physics Department, Southern Methodist University, Dallas TX, United States of America*
- <sup>41</sup>*Physics Department, University of Texas at Dallas, Richardson TX, United States of America*
- <sup>42</sup>*DESY, Hamburg and Zeuthen, Germany*
- <sup>43</sup>*Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany*
- <sup>44</sup>*Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany*
- <sup>45</sup>*Department of Physics, Duke University, Durham NC, United States of America*
- <sup>46</sup>*SUPA-School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
- <sup>47</sup>*INFN Laboratori Nazionali di Frascati, Frascati, Italy*
- <sup>48</sup>*Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany*
- <sup>49</sup>*Section de Physique, Université de Genève, Geneva, Switzerland*
- <sup>50a</sup>*INFN Sezione di Genova, Italy*
- <sup>50b</sup>*Dipartimento di Fisica, Università di Genova, Genova, Italy*
- <sup>51a</sup>*E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia*
- <sup>51b</sup>*High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia*
- <sup>52</sup>*II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany*
- <sup>53</sup>*SUPA-School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
- <sup>54</sup>*II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany*
- <sup>55</sup>*Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France*



- <sup>56</sup>*Department of Physics, Hampton University, Hampton VA, United States of America*
- <sup>57</sup>*Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, United States of America*
- <sup>58a</sup>*Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
- <sup>58b</sup>*Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
- <sup>58c</sup>*ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany*
- <sup>59</sup>*Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan*
- <sup>60a</sup>*Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China*
- <sup>60b</sup>*Department of Physics, The University of Hong Kong, Hong Kong, China*
- <sup>60c</sup>*Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China*
- <sup>61</sup>*Department of Physics, Indiana University, Bloomington IN, United States of America*
- <sup>62</sup>*Institut für Astro-und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria*
- <sup>63</sup>*University of Iowa, Iowa City IA, United States of America*
- <sup>64</sup>*Department of Physics and Astronomy, Iowa State University, Ames IA, United States of America*
- <sup>65</sup>*Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia*
- <sup>66</sup>*KEK, High Energy Accelerator Research Organization, Tsukuba, Japan*
- <sup>67</sup>*Graduate School of Science, Kobe University, Kobe, Japan*
- <sup>68</sup>*Faculty of Science, Kyoto University, Kyoto, Japan*
- <sup>69</sup>*Kyoto University of Education, Kyoto, Japan*
- <sup>70</sup>*Department of Physics, Kyushu University, Fukuoka, Japan*
- <sup>71</sup>*Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina*
- <sup>72</sup>*Physics Department, Lancaster University, Lancaster, United Kingdom*
- <sup>73a</sup>*INFN Sezione di Lecce, Italy*
- <sup>73b</sup>*Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy*
- <sup>74</sup>*Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom*
- <sup>75</sup>*Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia*
- <sup>76</sup>*School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom*
- <sup>77</sup>*Department of Physics, Royal Holloway University of London, Surrey, United Kingdom*
- <sup>78</sup>*Department of Physics and Astronomy, University College London, London, United Kingdom*
- <sup>79</sup>*Louisiana Tech University, Ruston LA, United States of America*
- <sup>80</sup>*Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France*
- <sup>81</sup>*Fysiska institutionen, Lunds universitet, Lund, Sweden*
- <sup>82</sup>*Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain*
- <sup>83</sup>*Institut für Physik, Universität Mainz, Mainz, Germany*
- <sup>84</sup>*School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom*
- <sup>85</sup>*CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France*
- <sup>86</sup>*Department of Physics, University of Massachusetts, Amherst MA, United States of America*
- <sup>87</sup>*Department of Physics, McGill University, Montreal QC, Canada*
- <sup>88</sup>*School of Physics, University of Melbourne, Victoria, Australia*
- <sup>89</sup>*Department of Physics, The University of Michigan, Ann Arbor MI, United States of America*
- <sup>90</sup>*Department of Physics and Astronomy, Michigan State University, East Lansing MI, United States of America*
- <sup>91a</sup>*INFN Sezione di Milano, Italy*
- <sup>91b</sup>*Dipartimento di Fisica, Università di Milano, Milano, Italy*
- <sup>92</sup>*B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus*
- <sup>93</sup>*National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus*
- <sup>94</sup>*Department of Physics, Massachusetts Institute of Technology, Cambridge MA, United States of America*
- <sup>95</sup>*Group of Particle Physics, University of Montreal, Montreal QC, Canada*
- <sup>96</sup>*P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia*
- <sup>97</sup>*Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia*
- <sup>98</sup>*National Research Nuclear University MEPhI, Moscow, Russia*
- <sup>99</sup>*D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia*
- <sup>100</sup>*Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany*
- <sup>101</sup>*Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany*
- <sup>102</sup>*Nagasaki Institute of Applied Science, Nagasaki, Japan*
- <sup>103</sup>*Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan*
- <sup>104a</sup>*INFN Sezione di Napoli, Italy*
- <sup>104b</sup>*Dipartimento di Fisica, Università di Napoli, Napoli, Italy*
- <sup>105</sup>*Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, United States of America*
- <sup>106</sup>*Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands*
- <sup>107</sup>*Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands*
- <sup>108</sup>*Department of Physics, Northern Illinois University, DeKalb IL, United States of America*

- <sup>109</sup>*Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia*
- <sup>110</sup>*Department of Physics, New York University, New York NY, United States of America*
- <sup>111</sup>*Ohio State University, Columbus OH, United States of America*
- <sup>112</sup>*Faculty of Science, Okayama University, Okayama, Japan*
- <sup>113</sup>*Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, United States of America*
- <sup>114</sup>*Department of Physics, Oklahoma State University, Stillwater OK, United States of America*
- <sup>115</sup>*Palacký University, RCPTM, Olomouc, Czech Republic*
- <sup>116</sup>*Center for High Energy Physics, University of Oregon, Eugene OR, United States of America*
- <sup>117</sup>*LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France*
- <sup>118</sup>*Graduate School of Science, Osaka University, Osaka, Japan*
- <sup>119</sup>*Department of Physics, University of Oslo, Oslo, Norway*
- <sup>120</sup>*Department of Physics, Oxford University, Oxford, United Kingdom*
- <sup>121a</sup>*INFN Sezione di Pavia, Italy*
- <sup>121b</sup>*Dipartimento di Fisica, Università di Pavia, Pavia, Italy*
- <sup>122</sup>*Department of Physics, University of Pennsylvania, Philadelphia PA, United States of America*
- <sup>123</sup>*Petersburg Nuclear Physics Institute, Gatchina, Russia*
- <sup>124a</sup>*INFN Sezione di Pisa, Italy*
- <sup>124b</sup>*Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
- <sup>125</sup>*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, United States of America*
- <sup>126a</sup>*Laboratorio de Instrumentacao e Fisica Experimental de Particulas-LIP, Lisboa, Portugal*
- <sup>126b</sup>*Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal*
- <sup>126c</sup>*Department of Physics, University of Coimbra, Coimbra, Portugal*
- <sup>126d</sup>*Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal*
- <sup>126e</sup>*Departamento de Fisica, Universidade do Minho, Braga, Portugal*
- <sup>126f</sup>*Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain*
- <sup>126g</sup>*Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal*
- <sup>127</sup>*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
- <sup>128</sup>*Czech Technical University in Prague, Praha, Czech Republic*
- <sup>129</sup>*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
- <sup>130</sup>*State Research Center Institute for High Energy Physics, Protvino, Russia*
- <sup>131</sup>*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
- <sup>132</sup>*Ritsumeikan University, Kusatsu, Shiga, Japan*
- <sup>133a</sup>*INFN Sezione di Roma, Italy*
- <sup>133b</sup>*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
- <sup>134a</sup>*INFN Sezione di Roma Tor Vergata, Italy*
- <sup>134b</sup>*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
- <sup>135a</sup>*INFN Sezione di Roma Tre, Italy*
- <sup>135b</sup>*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
- <sup>136a</sup>*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies-Université Hassan II, Casablanca, Morocco*
- <sup>136b</sup>*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
- <sup>136c</sup>*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*
- <sup>136d</sup>*Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco*
- <sup>136e</sup>*Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco*
- <sup>137</sup>*DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France*
- <sup>138</sup>*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, United States of America*
- <sup>139</sup>*Department of Physics, University of Washington, Seattle WA, United States of America*
- <sup>140</sup>*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
- <sup>141</sup>*Department of Physics, Shinshu University, Nagano, Japan*
- <sup>142</sup>*Fachbereich Physik, Universität Siegen, Siegen, Germany*
- <sup>143</sup>*Department of Physics, Simon Fraser University, Burnaby BC, Canada*
- <sup>144</sup>*SLAC National Accelerator Laboratory, Stanford CA, United States of America*
- <sup>145a</sup>*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*
- <sup>145b</sup>*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
- <sup>146a</sup>*Department of Physics, University of Cape Town, Cape Town, South Africa*
- <sup>146b</sup>*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
- <sup>146c</sup>*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
- <sup>147a</sup>*Department of Physics, Stockholm University, Sweden*

- <sup>147b</sup>*The Oskar Klein Centre, Stockholm, Sweden*
- <sup>148</sup>*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
- <sup>149</sup>*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, United States of America*
- <sup>150</sup>*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*
- <sup>151</sup>*School of Physics, University of Sydney, Sydney, Australia*
- <sup>152</sup>*Institute of Physics, Academia Sinica, Taipei, Taiwan*
- <sup>153</sup>*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
- <sup>154</sup>*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
- <sup>155</sup>*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
- <sup>156</sup>*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
- <sup>157</sup>*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
- <sup>158</sup>*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
- <sup>159</sup>*Department of Physics, University of Toronto, Toronto ON, Canada*
- <sup>160a</sup>*TRIUMF, Vancouver BC, Canada*
- <sup>160b</sup>*Department of Physics and Astronomy, York University, Toronto ON, Canada*
- <sup>161</sup>*Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan*
- <sup>162</sup>*Department of Physics and Astronomy, Tufts University, Medford MA, United States of America*
- <sup>163</sup>*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
- <sup>164</sup>*Department of Physics and Astronomy, University of California Irvine, Irvine CA, United States of America*
- <sup>165a</sup>*INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy*
- <sup>165b</sup>*ICTP, Trieste, Italy*
- <sup>165c</sup>*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*
- <sup>166</sup>*Department of Physics, University of Illinois, Urbana IL, United States of America*
- <sup>167</sup>*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
- <sup>168</sup>*Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*
- <sup>169</sup>*Department of Physics, University of British Columbia, Vancouver BC, Canada*
- <sup>170</sup>*Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada*
- <sup>171</sup>*Department of Physics, University of Warwick, Coventry, United Kingdom*
- <sup>172</sup>*Waseda University, Tokyo, Japan*
- <sup>173</sup>*Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel*
- <sup>174</sup>*Department of Physics, University of Wisconsin, Madison WI, United States of America*
- <sup>175</sup>*Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany*
- <sup>176</sup>*Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany*
- <sup>177</sup>*Department of Physics, Yale University, New Haven CT, United States of America*
- <sup>178</sup>*Yerevan Physics Institute, Yerevan, Armenia*
- <sup>179</sup>*Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France*

<sup>a</sup>Deceased.

<sup>b</sup>Also at Department of Physics, King's College London, London, United Kingdom.

<sup>c</sup>Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

<sup>d</sup>Also at Novosibirsk State University, Novosibirsk, Russia.

<sup>e</sup>Also at TRIUMF, Vancouver BC, Canada.

<sup>f</sup>Also at Department of Physics, California State University, Fresno CA, United States of America.

<sup>g</sup>Also at Department of Physics, University of Fribourg, Fribourg, Switzerland.

<sup>h</sup>Also at Tomsk State University, Tomsk, Russia.

<sup>i</sup>Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.

<sup>j</sup>Also at Università di Napoli Parthenope, Napoli, Italy.

<sup>k</sup>Also at Institute of Particle Physics (IPP), Canada.

<sup>l</sup>Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.

<sup>m</sup>Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.

<sup>n</sup>Also at Louisiana Tech University, Ruston LA, United States of America.

<sup>o</sup>Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.

<sup>p</sup>Also at Department of Physics, National Tsing Hua University, Taiwan.

<sup>q</sup>Also at Department of Physics, The University of Texas at Austin, Austin TX, United States of America.

<sup>r</sup>Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.

<sup>s</sup>Also at CERN, Geneva, Switzerland.

<sup>t</sup>Also at Georgian Technical University (GTU), Tbilisi, Georgia.

- <sup>u</sup>Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
- <sup>v</sup>Also at Manhattan College, New York NY, United States of America.
- <sup>w</sup>Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
- <sup>x</sup>Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.
- <sup>y</sup>Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
- <sup>z</sup>Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
- <sup>aa</sup>Also at Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy.
- <sup>bb</sup>Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
- <sup>cc</sup>Also at Section de Physique, Université de Genève, Geneva, Switzerland.
- <sup>dd</sup>Also at International School for Advanced Studies (SISSA), Trieste, Italy.
- <sup>ee</sup>Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, United States of America.
- <sup>ff</sup>Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
- <sup>gg</sup>Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.
- <sup>hh</sup>Also at National Research Nuclear University MEPhI, Moscow, Russia.
- <sup>ii</sup>Also at Department of Physics, Stanford University, Stanford CA, United States of America.
- <sup>jj</sup>Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
- <sup>kk</sup>Also at Department of Physics, Oxford University, Oxford, United Kingdom.
- <sup>ll</sup>Also at Department of Physics, The University of Michigan, Ann Arbor MI, United States of America.
- <sup>mm</sup>Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.
- <sup>nn</sup>Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.